

SHORT COMMUNICATION

Modelling of Heat Source Dynamics in Electron Beam Welding**Suresh Akella¹, Harinadh Vemanaboina¹, Ramesh Kumar Buddu²**¹Sreyas Institute of Engineering & Technology, Hyderabad-500068, India.²FRMDC Division, Institute for Plasma Research, Bhat, Gandhinagar-382428, India.

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ABSTRACT

Electron beam welding is one of the important fabrication processes for fusion reactor components subsystems. This weld process offers superior advantages over other techniques by producing very low distortions, high aspect ratios, lower stresses and deep penetration with single pass. A complete understanding of the electron beam welding with heat flux and temperature profiles during the beam metal interaction is still not completely understood. In addition, the formation of the weld bead geometry in weld pool is fully governed by the plasma keyhole kinetics and their control over the depth is due to the combined gaseous (vapor) and liquid molten material during high speed electron beam welding process. The weld defects caused by the process are completely dependent on the shape and movement of the keyhole plasma during the electron beam interaction within the material. The present investigations are focused on understanding the keyhole effects on the weld bead formation with various heat input parameters like flux and power density. Corresponding analytical estimations based on point and line source models have been attempted to estimate the temperature profile during the keyhole formation. The conductive and radioactive regimes are considered for the temperature profile estimation of the molten pool cavity over the penetration depths. The power density distribution over the depth of the materials for stainless steel is attempted and temperature and heat flux distributions are evaluated. Analytical results are presented and potential applications with electron beam welding in the fusion reactor are highlighted.

Keywords: Electron beam welding, Fusion reactor components, Distortion, Aspect ratio, Stress.**1. OBJECTIVES**

- To understand Kaplan keyhole formation
- Adopting laser keyhole model to EBW
- Gaussian distribution of heat flux
- Depth of penetration
- FEM analysis
- Temperature, residual stresses and distortion

Key whole profile for higher welding speeds model is for blind key hole. In EBW, key hole is open.

1.1. Keyhole profile

[1] Key hole is a capillary formed by high intensity laser beam that enables energy entrainment and increase in depth without increasing weld width. To keep the keyhole

open, energy and pressure balance at the keyhole wall must be satisfied. The metal vapor inside the keyhole keeps the keyhole open acting against the surface tension. The metal vapor flows out of the keyhole and is replaced by evaporated material continuously. The evaporated molten metal is only a small amount and majority of molten metal flows due to pressure difference of the keyhole sides. Laser beam power is absorbed mostly by Fresnel and plasma absorption. Metal temp reaches the temperature higher than the melting temperature and gets ionized. The resulting plasma absorbs infrared radiation of CO₂ laser by inverse bremsstrahlung absorption. Fresnel absorption is due to multiple reflections of beam inside the keyhole. Asymmetry occurs between front and

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back wall due to deferring heat conduction, where energy balance is required to obtain the keyhole profile. Modeling of various absorption mechanisms, thermodynamic and gas dynamic vapor inside keyhole calculations and energy balance at the keyhole wall x,y,z cartesian & r,φ, z cylindrical co-ordinates are used. Rosenthal gave a temperature field T(r,φ), solution in the work piece as shown in equation (1.1). [2-6]

$$T(r, \phi) = T_a + P' / (2 * \pi * K_{th}) * K_0(Pe', r) * e^{-(Pe' * r * \cos \phi)} \quad (1.1)$$

where T_a is ambient temperature, K_{th} refers to the thermal conductivity, Pe' is modified Peclet number, $K_0(Pe', r)$ is the modified Bessel function of second kind and zeroth order and T is singular at the origin where the line source for power per unit depth (P') is located [7- 12].

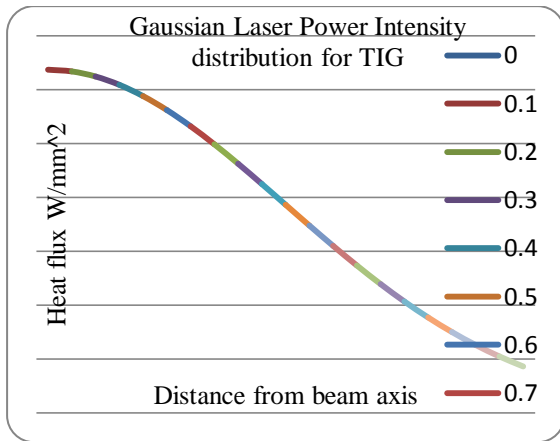


Figure 1. Gaussian laser power intensity distribution for TIG

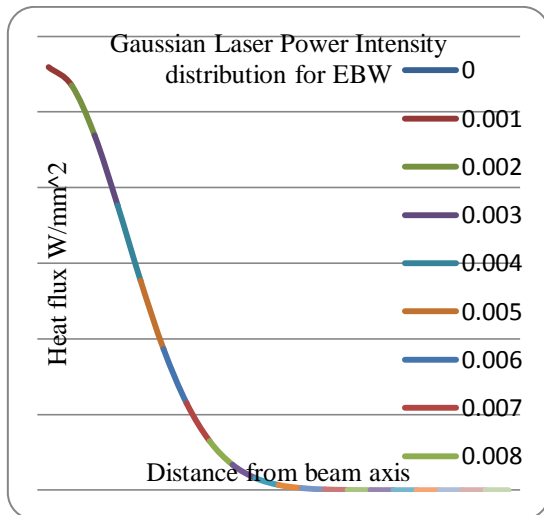


Figure 2. Gaussian laser power intensity distribution for EBW

Figures 1, 2, 3, 4, depict the Gaussian laser power intensity distribution for TIG, Gaussian laser power intensity distribution for EBW, heat flux models and comparison of Gaussian and constant models accordingly. Figures A1, A2, A3, A4, A5 represent the Gaussian heat flux for TIG and EBW processes, ANSYS output 1, plot of distance versus stress 1, ANSYS output 2 and plot of distance versus stress 2 respectively.

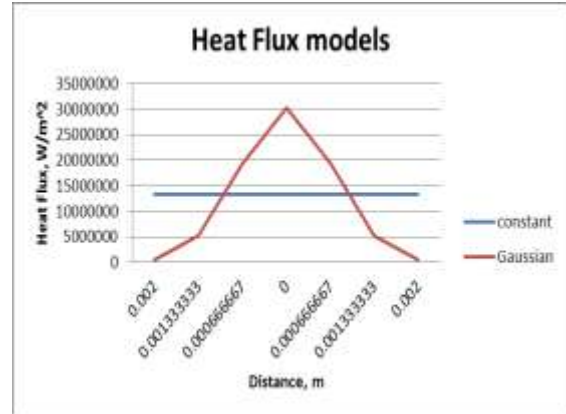


Figure 3. Heat flux models

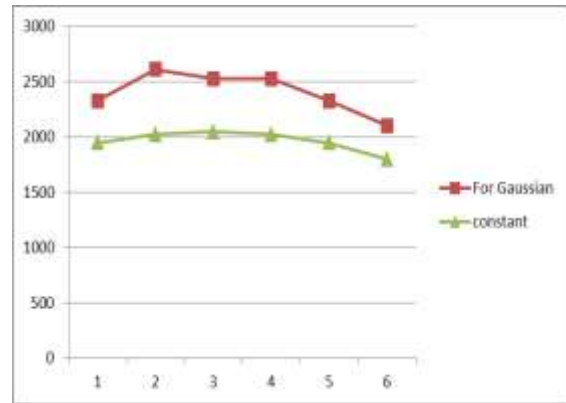


Figure 4. Comparison

2. CONCLUSION

The Gaussian heat flux distribution is used to represent keyhole heat power which is absorbed as per Kaplan's model. The heat absorbed is compared with constant heat flux models.

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APPENDIX

Kaplan Key Hole model for LASER & EBW

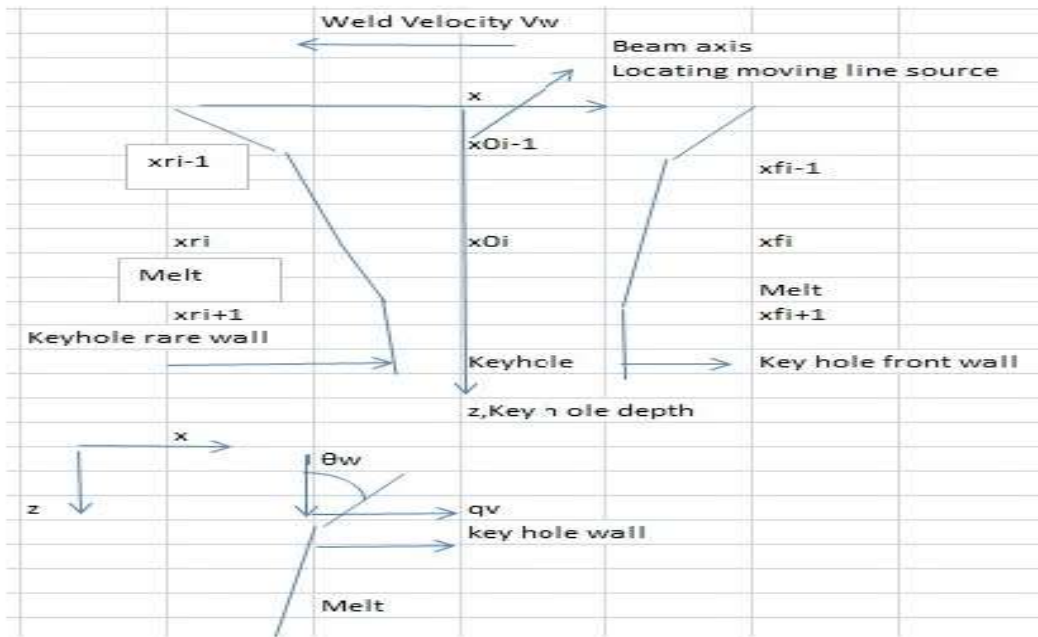


Figure A1. Gaussian heat flux for TIG & EBW processes

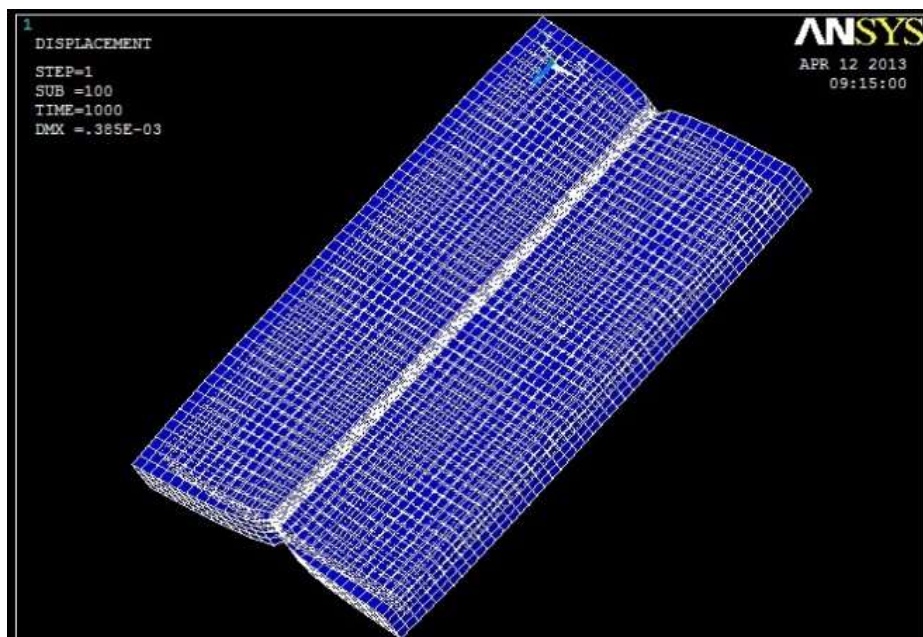


Figure A2. ANSYS output 1

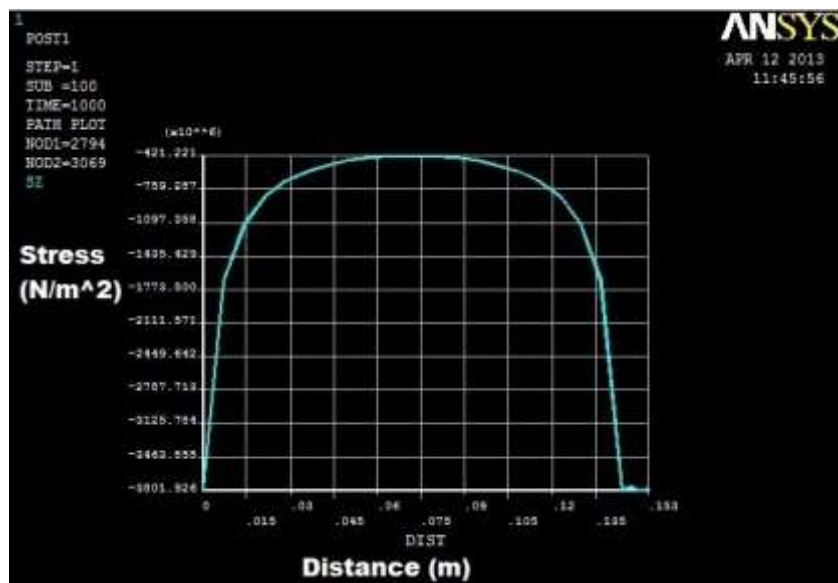


Figure A3. Plot of distance vs stress 1

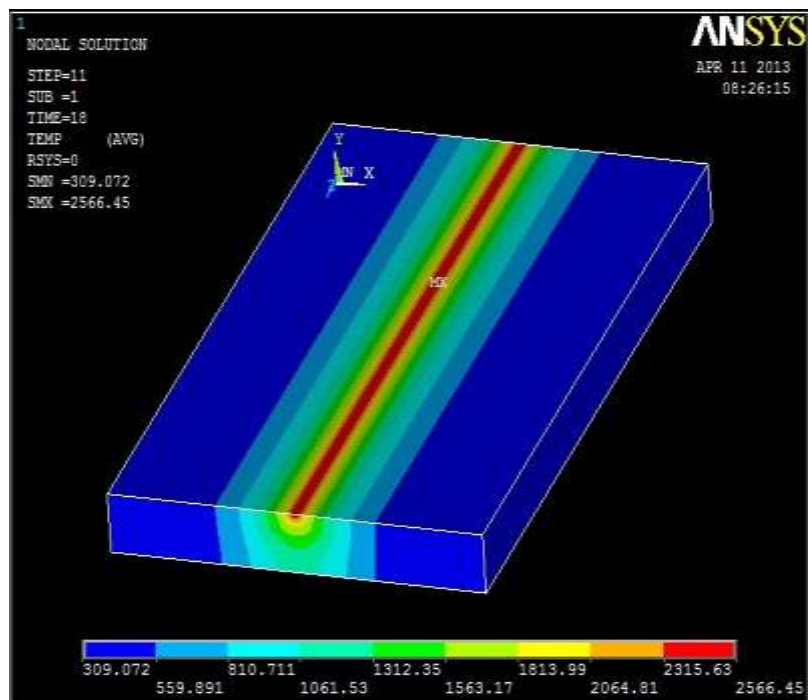


Figure A4. ANSYS output 2

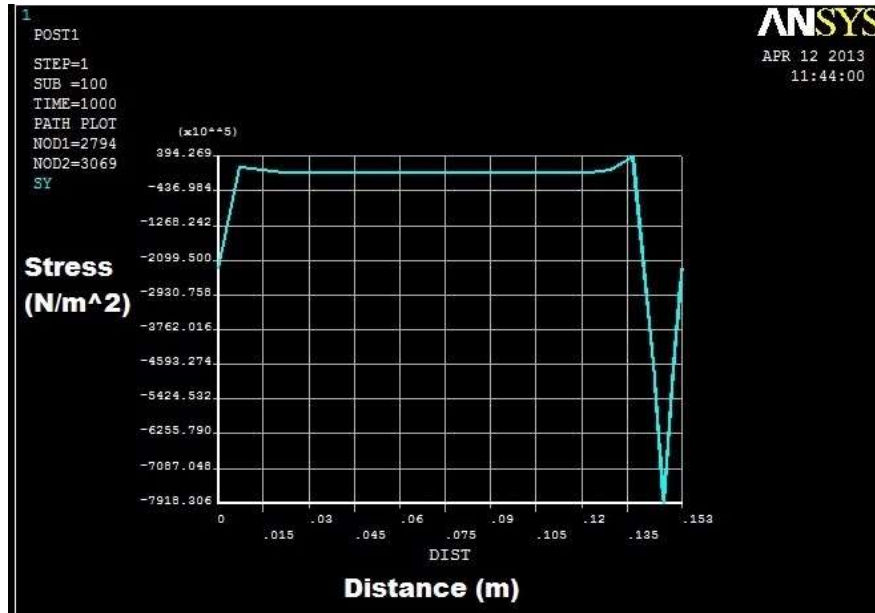


Figure A5. Plot of distance versus stress 2